U.S. DEPARTMENT OF ENERGY | Nuclear Energy

US DOE Reactor R&D Programs

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Overview of the NE Reactor Program

Objectives:

- **Facilitate operation of existing plants and construction of new plants**
- **Develop capabilities that support current and future US nuclear enterprise objectives:**
  - Create new solutions addressing national priorities including energy security and the environment
  - Enhance US competitiveness
- **Facilitate development of new concepts**

Phases:

1: Support current fleet (ongoing)

2: Build new “conventional” large, medium and small reactors (~2020 and beyond)

3: Develop advanced systems for non-electric applications (ongoing)

4: Develop advanced systems for electric and/or waste management applications (~ 2040 and beyond)

[programs that support fast reactor development will be discussed in the Transmutation presentation]

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Reactor Program Summary (1)

Reactor Program	Benefits	Issues	Supporting Programs *	DOE Capability Development
Phase 1: **Light Water Reactor Sustainability (LWRS)**	**Lifetime extension for existing reactors, uprates**	• **Aging** • **Safety margins** • **Fuel performance** • **Instrumentation & control**	• **(LWRS)** • **M&S Hub** • **NEET** • **NEAMS**	• **Material sciences** • **Modeling and simulation** • **Fuel development** • **Instrumentation and control** • **Risk informed safety margins** • **Fabrication**
Phase 2: **Small Modular Reactors (SMR)**	**Distributed and affordable power, incremental capacity**	• **Licensing** • **Cost** • **Performance**	• **(Reactor Concepts RD&D)** • **M&S Hub** • **NEET** • **NEAMS**	

* Programs identified in the President's FY 2011 budget proposal

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Reactor Program Summary (2)

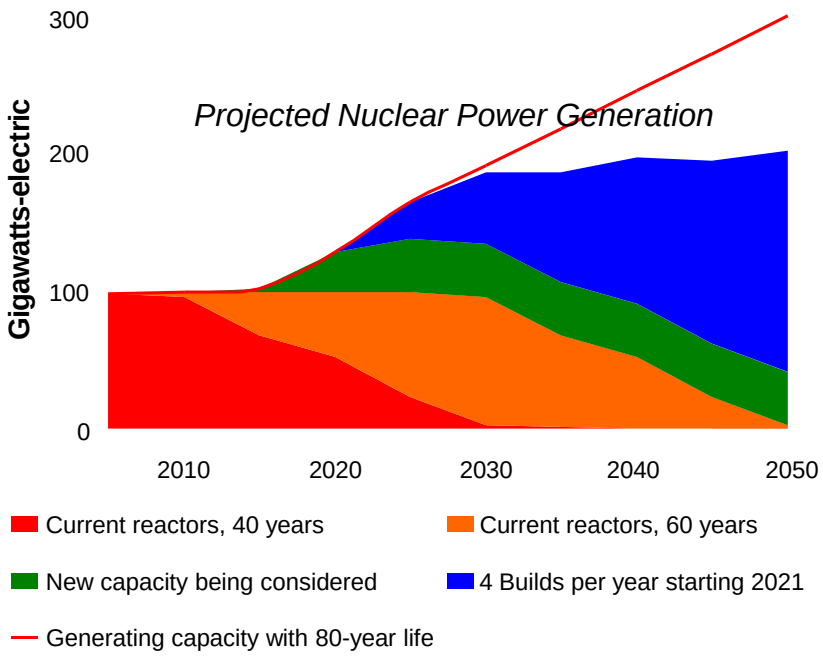
Reactor Program	Benefits	Issues	Supporting Programs *	DOE Capability Development
Phase 3: **Next Generation Nuclear Plant**	**High efficiency electricity and high temperature heat generation**	• **Licensing** • **Performance**	• **(Reactor Concepts RD&D / NGNP)** • **NEET / M&S Hub** • **NEAMS**	• **Heat transport systems** • **Modeling and simulation** • **Advanced fuels** • **High temperature materials**
Phase 4: **Future Reactors** - Once Through - Advanced Fuel Cycles	**Once Through** • Cost reduction • Increased safety • Waste reduction **Advanced Fuel Cycles** • Waste management solutions	**Once Through** • Cost • Fuel performance **Advanced Fuel Cycles** • Cost • Fuel performance • Nonproliferation	• **(Reactor Concepts RD&D)** • **NEET/M&S Hub** • **NEAMS** • **FCRD**	• **High burnup fuel development** • **Development of fundamental process understanding** • **Materials sciences** • **Energy conversion improvements** • **Modeling and simulation**

- **Base activities that support multiple reactor programs include:**
  - **Nuclear Energy Enabling Technologies (NEET)**
    - Transformative Nuclear Concepts R&D
    - Crosscutting Technology Development
    - Energy Innovation Hub for Modeling and Simulation (M&S Hub)
  - **Nuclear Energy Advanced Modeling and Simulation (NEAMS)**

Phase 1: Support Current Fleet

Life Extension

- **Benefits:**
  - **Current fleet provides >70% of non-greenhouse gas emitting electricity**
  - **Existing reactors reduce burden of new clean electricity that will need to come online**
  - **Favorable economics**
- **Issues:**
  - **Current nuclear plants will retire between 2029 – 2056**
    - *New nuclear build rate will not replace plant retirements*
    - *Cost to replace the current fleet exceeds $600B*
    - *Steep reduction in emission-free generation*
- **Light Water Reactor Sustainability (LWRS) Program**
  - **Possible basis for life time extension**
  - **Provides basis for uprates**

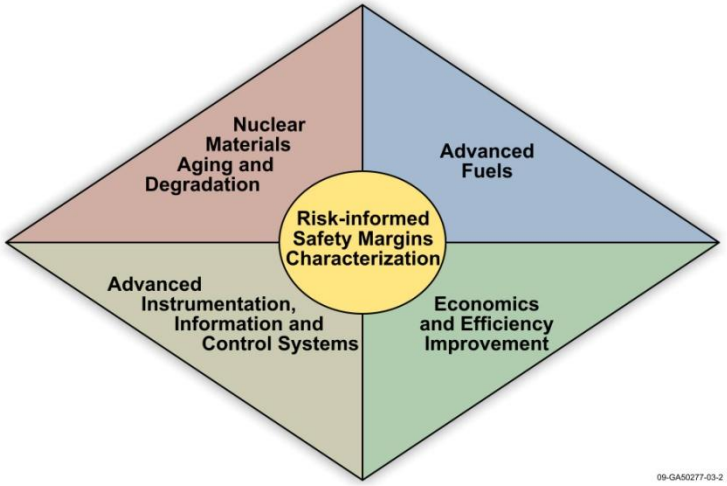


Phase 1: Support Current Fleet

Life Extension R&D

- **R&D Program Goals**
  - Develop fundamental scientific basis to allow continued safe long-term operation of existing LWRs
  - Develop improvements that contribute to long-term economic viability of existing nuclear power plants

- **R&D Program Scope**
  - Materials Aging and Degradation
  - Risk-Informed Safety Margin Characterization
  - Efficiency improvements
  - Advanced Instrumentation and Controls
  - Advanced Fuel Development



Phase 2: Build New Reactors

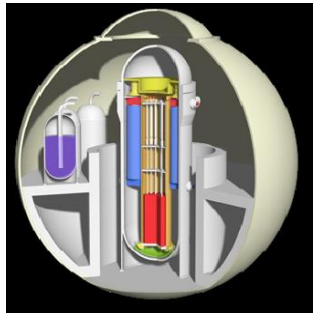
Small Modular Reactor (SMR) Development

- **The US is moving aggressively toward designing and promoting SMRs, and DOE plans to provide critical support**
- **Benefits:**
  - Revitalization of US industry leadership in innovative nuclear design, engineering and manufacturing
  - Allows nuclear power option to be more affordable and suitable to a broader range of domestic and international customers
  - Jobs span high-tech manufacturing, technical and operational fields
  - Allows smaller initial investment and incremental capacity addition
  - Reduces siting challenges such as access, electrical grid and water rights
- **Issues:**
  - **Technical challenges such as:**
    - *Different designs requiring different measurement and control options*
    - *Integral designs impose material, inspection, and maintenance challenges*
  - **Regulatory challenges such as:**
    - *Departure from traditional licensing experience*
      - *Accommodation of safer and simpler designs*
  - **Institutional challenges such as:**
    - *Performance uncertainty introduced by new designs and technologies*
    - *Cost (economies of series vs economies of scale)*

Phase 2: Build New Reactors

Small Modular Reactor RD&D

- **Design certification partnerships**
  - Establish cost-shared projects with industry partners to accelerate design certification
- **SMR assessment tools**
  - Support development of new analysis tools, codes and standards, and cost models to support objective assessments of SMR safety, performance and economics
- **SMR technology R&D**
  - Develop technologies that further minimize costs or enable advanced SMR features and functionality
- **Advanced SMR concepts**
  - Develop innovative concepts that use advanced technologies to achieve expanded SMR functionality



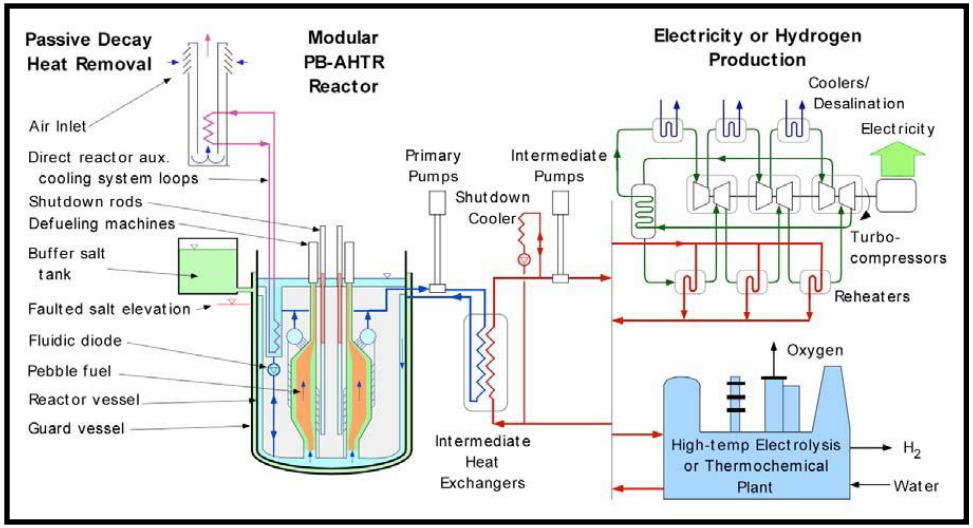
WEC IRIS Reactor Concept

NuScale Reactor Concept

Phase 2: Build New Reactors

Reactor Concepts RD&D

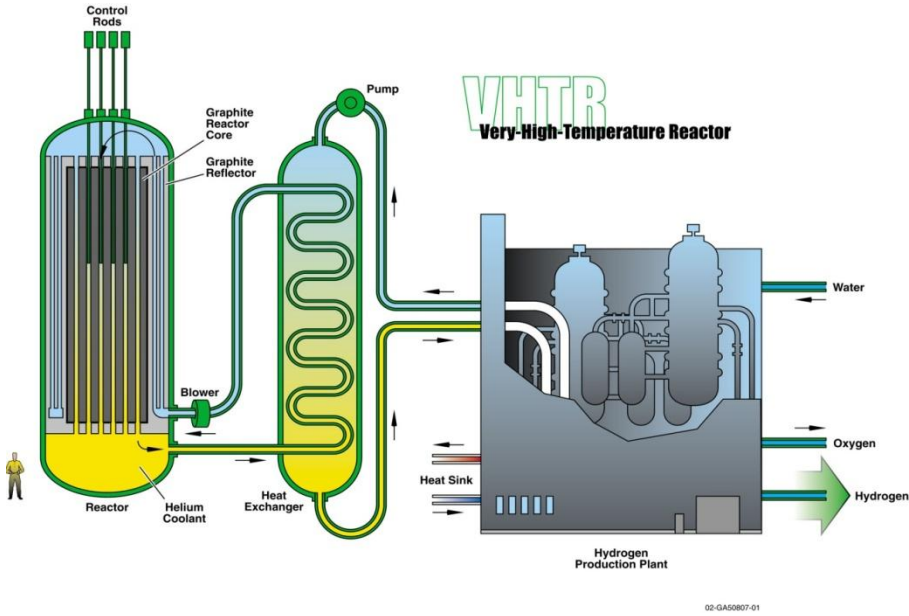
- **Future progress will be enabled by developing a strong set of capabilities that enable significant (possibly transformational) solutions**
- **New concepts, with significantly improved performance, have been proposed and need to be fostered**
  - A typical example is the AHTR
    - *High temperature, molten salt cooled, TRISO fueled, compact reactor*
- **We will rely on competitive processes to create new ideas**



Phase 3: Develop Advanced Systems for Non-Electric Applications

Next Generation Nuclear Plant and New Markets for Nuclear Power

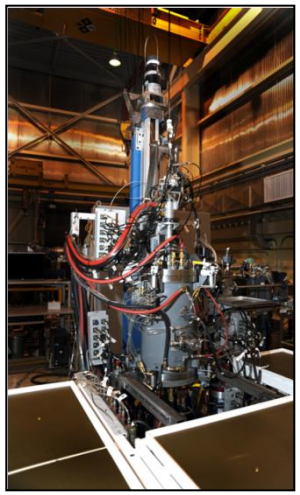
- **Benefits:**
  - **Can facilitate a transition away from fossil fuels to secure environmentally sustainable energy for industry**
    - *Transition will significantly enhance the nation's energy security and independence*
- **Issues:**
  - **Technical challenges such as:**
    - *Development of fuels, materials, and models*
  - **Regulatory challenges such as:**
    - *Departure from traditional licensing experience*
    - *Operational differences such as staged construction and multi-module control systems*
  - **Institutional challenges such as:**
    - *Performance uncertainty introduced by new designs and technologies*
    - *Adoption of non-electric uses for nuclear energy*

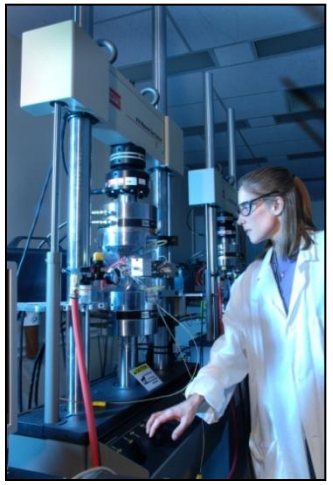


Phase 3: Develop Advanced Systems for Non-Electric Applications

Process Heat Applications R&D

- **High Temperature Gas Reactor**
  - Fuels
  - Graphite
  - High Temperature Materials
  - Design and Safety Methods
- **Reactor End User Interface**
  - Heat Transport
  - Hydrogen and hybrid systems
- **Licensing, Economics and the Business Case**
- **Advanced reactors for resource extension and waste management (i.e., Phase 4) will be discussed under the Fuel Cycle topic**

Crosscutting Programs

Nuclear Energy Enabling Technologies

- **The Nuclear Energy Enabling Technologies (NEET) Technology Development Program will support crosscutting activities relevant to multiple reactor and fuel cycle concepts**
  - Promotes generation of new ideas and fosters exploration of technology options

- **The program includes three elements:**
  - Transformative Nuclear Concepts R&D
  - Crosscutting Technology Development
  - Energy Innovation Hub for Modeling and Simulation

Crosscutting Programs

Transformative Nuclear Concepts R&D

- **Encourages identification and development of "outside - the - box" options associated with all aspects of civilian nuclear energy programs**
  - Ensures that good ideas have sufficient outlet for exploration

- **Scope of eligible topics is not specific to any on-going mission activities**
  - *Investigator-initiated research selected through open competition*
  - *Will provide needed creative component to NE programs*
  - *Needs to be integrated with other competitive elements of NE programs*
  - *Encourages broad participation across national laboratories, universities, research institutions, and industry*

Crosscutting Programs

Crosscutting Technology Development

- **Provides either crosscutting or enabling technologies to support multiple reactor concepts**
- **“Base” program for underlying technologies with broad application focus**
- **Key to success for long term NE vision**
- **Crosscuts include:**
  - *Reactor Materials, Advanced Sensors and Instrumentation, Proliferation Risk Assessment, Advanced Methods for Manufacturing*

Crosscutting Programs

Modeling and Simulation Energy Innovation Hub

- **Consortium for Advanced Simulation of Light Water Reactors (CASL) mission:**
  - **Develop and apply the virtual reactor to address critical performance goals for nuclear power**

1

Reduce capital and operating costs per unit energy by:

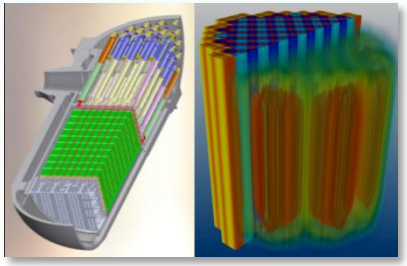
- Power uprates
- Lifetime extension

2

Reduce nuclear waste volume generated by enabling higher fuel burnups

3

Enhance nuclear safety by enabling high-fidelity predictive capability for component and system performance from beginning of life through failure



Crosscutting Programs

CASL vision: Create a Virtual Reactor for Predictive Simulation of LWRs

Leverage

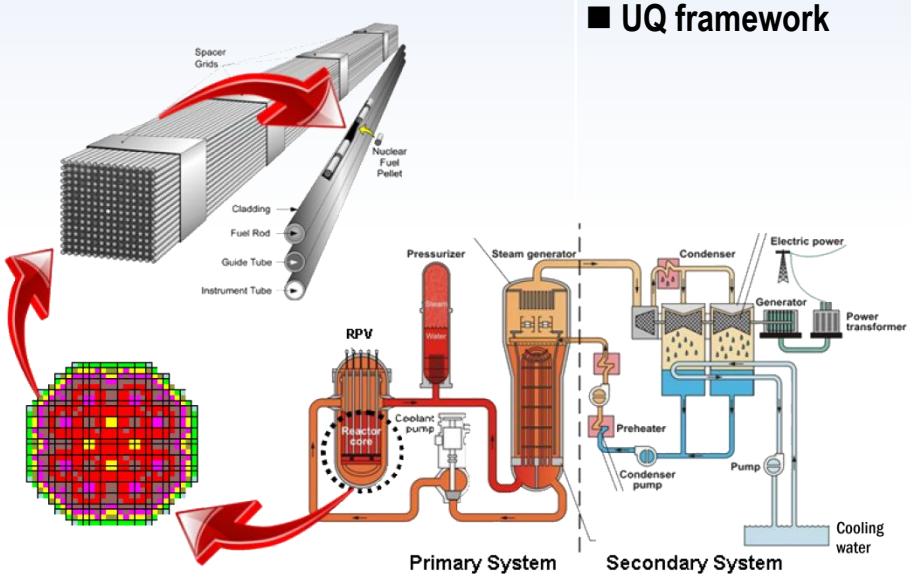
- Current state-of-the-art neutronics, thermal-fluid, structural, and fuel performance applications
- Existing systems and safety analysis simulation tools

Develop

- New requirements-driven physical models
- Efficient, tightly-coupled multi-scale/multi-physics algorithms and software with quantifiable accuracy
- Improved systems and safety analysis tools
- UQ framework

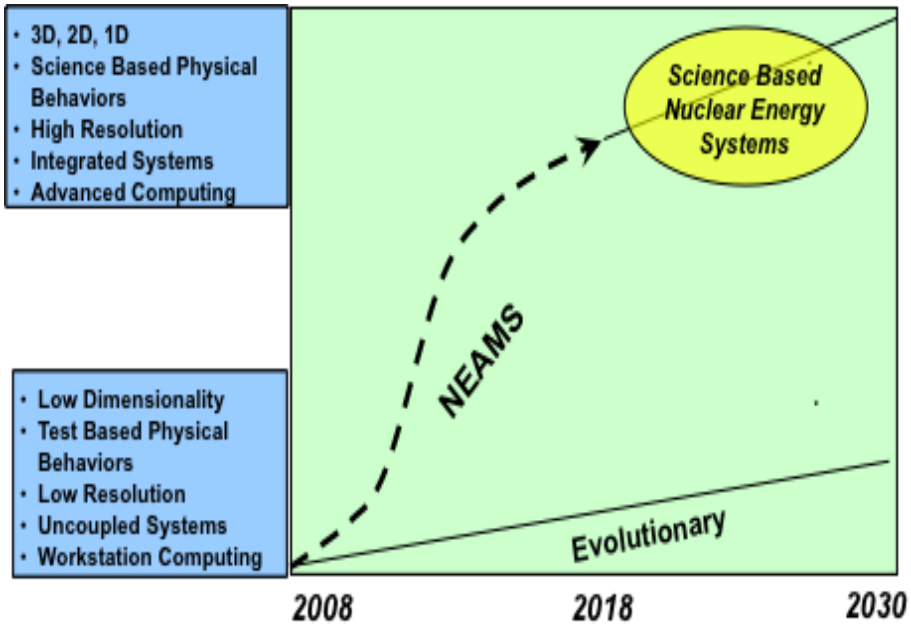
Deliver

- An unprecedented predictive simulation tool for simulation of physical reactors
- Architected for platform portability ranging from desktops to DOE's leadership-class and advanced architecture systems (large user base)
- Validation basis against 60% of existing U.S. reactor fleet (PWRs), using data from TVA reactors
- Base M&S LWR capability



Nuclear Energy Advanced Modeling and Simulation (NEAMS) Strategy

- **Continuously increasing capability for predictive simulation of:**
  - Nuclear reactors
  - Fuels
  - Safeguarded separations
  - Waste forms in a repository environment
- **Modeling and simulation capabilities that can be used to create scientific understanding, design, and license nuclear energy technologies for:**
  - Sustainment of the current LWR fleet
  - Near term deployment of new advanced reactors
  - Innovative uses of nuclear energy
  - Proper disposal of waste
  - Closing the fuel cycle
- **Flexible capabilities that can be applied to different types of nuclear energy technologies**



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Summary: Developing Future Reactors

- **Significant reactor performance improvements are possible, for example:**
  - Higher efficiencies from higher temperatures
  - Lower costs from more compact designs and breakthrough materials
  - Higher reliability from improved fabrication techniques
  - Lower volumetric waste production from higher burnup fuels
  - Safer and cheaper concepts enabled by modern modeling and simulation
- **Reactor programs support NE's goals as defined in the R&D Roadmap**
- **DOE will also support US industry competitiveness**
  - Facilitate construction / licensing
  - Provide capabilities
  - Envision and develop new concepts